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IMPACT OF PRARE ON ERS-2 POD

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ABSTRACT

For the analysis of radar altimeter data the precise knowledge of the satellite's ephemerides is an important prerequisite. For the ERS-2 satellite, launched April 21, 1995, the PRARE (Precise Range and Range Rate Equipment) system offers a new additional tool for the precise orbit determination besides the usual satellite laser ranges (SLR). In the following some POD tests are described. Although these tests are based on a preliminary set of the so-called revision 5 data, they clearly demonstrate the high quality of the data.

INTRODUCTION

For the precise analysis of the altimeter data of oceanic satellites like ERS-1/2 and Topex/Poseidon the accurate knowledge of the satellite's position, especially in the radial direction is an essential prerequisite. In order to obtain a radial accuracy of about 8 cm, for ERS-1 the primary tracking information (satellite laser ranges) has been combined with altimeter data. The altimeter measurements were not taken directly, but in form of altimeter crossover height differences (i.e. height differences at points where the ascending and descending orbit arcs are crossing), in order to prevent the oceanic signal to be absorbed in the orbit.

On April 21, 1995, the successor ERS-2 has been launched successfully. Besides the laser retroreflector it is also equipped with the PRARE (Precise Range and Range Rate Equipment) microwave instrument. While this had failed on ERS-1 due to radiation damage, it is properly working on ERS-2 (as before on Meteor-3/7). So this provides an additional new tracking information for orbit determination purposes. In the following, after a short description of the PRARE system, a report will be given about the tracking data acquired so far. Afterwards the PRARE data will be used for orbit determination purposes and the achieved results will be discussed.

THE PRARE TRACKING SYSTEM

The Precise Range And Range-Rate Equipment PRARE is a new space-borne, two-way, two-frequency microwave tracking system with onboard data storage and central data preprocessing which allows data analysis within a very short time. It has been developed during the past 10 years on behalf of the German Space Agency DARA GmBH by the Institute for Navigation of the University Stuttgart and the GeoForschungsZentrum Potsdam. PRARE has been tested between February 1994 and September

1995 onboard the Russian meteorological satellite METEOR-3/7. Since April 21, 1995 the system is operational in a redundant configuration onboard the second ESA European Remote Sensing satellite ERS-2. The highly precise tracking information are used to derive on a regular basis preliminary and precise ERS-2 orbits as well as other geodetic/geophysical parameters like Earth orientation, station coordinates or gravity field. The two-frequency down-link measurements are used to correct the ionospheric influences on the signals and to monitor the total electron content TEC of the ionosphere. Additionally it has been proved that PRARE can be used for clock synchronization.

The PRARE signals are based on a combination of high frequency carriers (X and S-band), appropriate PN-codes (10 and 1 MChips) and spread-spectrum binary data (2/4 Kb/s). They are generated inside the space segment and permanently disseminated by two dipole antennas. The transportable and automatic operating ground stations receive the X-band downlink signal and demodulate the PN-code. Then the PN-sequence is remodulated on the X-band which is retransmitted to the space segment (regenerative transponders) containing ground station measurement data used for the preprocessing of the data. The ground stations being at the same time coherent, the carrier frequency of the up-link is in a well defined phase relationship to the downlink carrier frequency. Onboard the PRARE instrument measures both the two-way range and the received two-way Doppler-shifted signal very precisely by comparing the phase of the received signal to the phase of the on-board clock. The overall accuracy stems therefore mainly from this two-way configuration of the system which eliminates most clock errors of one-way systems. Figure 1 summarizes the measurement principle.

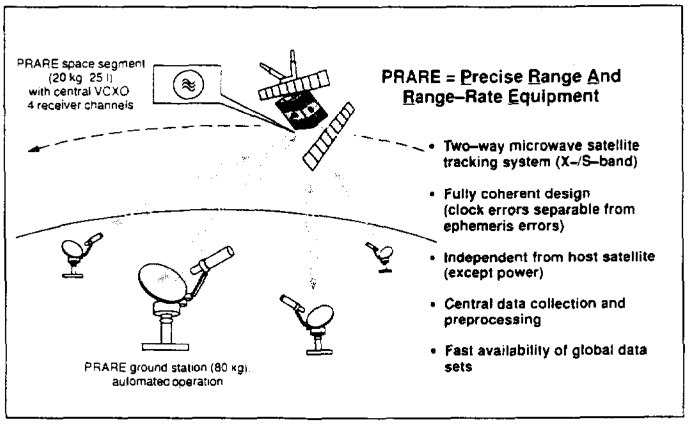

Fig.1: PRARE measurement principle

The PRARE ground segment consists of, beside a Monitoring and System Command Station in Stuttgart, a Master Station in Oberpfaffenhofen and a Calibration Station in Potsdam, of up to 27 Mission Execution Network stations owned and operated by 13 different international user groups. Today's status (July 1996) is shown in Figure 2.

PRARE DATA PREPROCESSING AND QUALITY

The onboard stored compressed PRARE science and housekeeping data are dumped during every satellite pass to the Monitor and System Command Station in Stuttgart and transmitted to the PRARE Master Station for generation of PRARE data products. The Master Station decodes these binary raw data files to physical chronologically sorted data. In a next step all corrections due to the PRARE measurement principle are applied. This takes also into account ground station and space segment calibration data derived during every satellite contact.

The 1 pps signal of the onboard PRARE clock, which is additionally modulated on the downlink signal, is compared with UTC using the Master Station timing system consisting of a GPS time receiver, 2 Rubidium clocks and a time interval counter. This PRARE onboard time vs. UTC clock model is generated on a routine basis to correct the time tag and the scale of the measurements during further preprocessing of the data. The total electron content of the ionosphere in slant and vertical direction can be derived from the ground station observed X/S travel time delays and is available as one of the PRARE products. Beside outlier detection several corrections to take into account atmospheric influences or geometric relationships at satellite and ground station are calculated to derive the PRARE full rate range and range rate products.

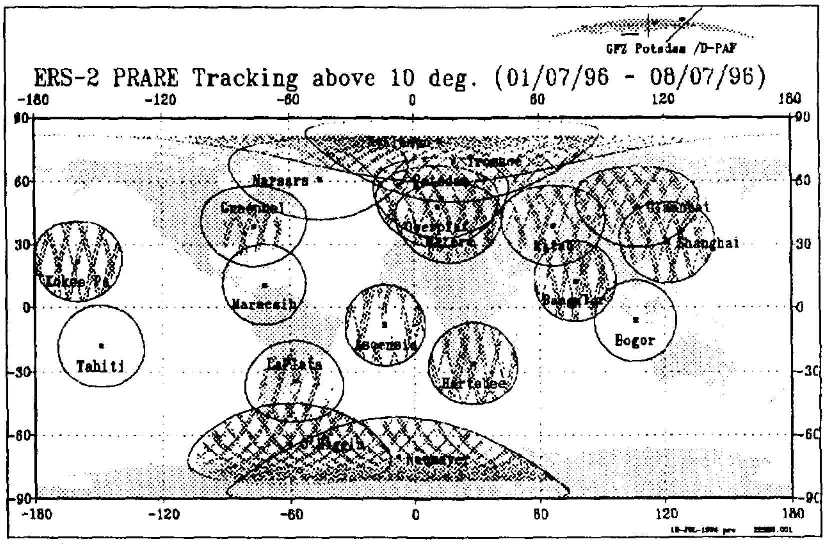

Fig.2: PRARE Station Network (as of July 1996)

In a final step these data are compressed to normal points where a further screening of the data takes place. All data are made available to the PRARE users on the GFZ/DC FTP server.

The PRARE system on ERS-2 acquires several hundred passes per week starting from nearly horizon. The overall noise of the PRARE full rate range data is below 3 cm and below 0.1 mm/s for range rate data (30 seconds integration interval).

PRECISE ORBIT DETERMINATION

Modeling

The POD has been performed with GFZ's own software EPOS (Earth Parameter & Orbit System). The models selected are those in use for the operational ERS POD at GFZ/D-PAF. The main model characteristics are: Earth gravity model PGM055 (based on GRIM4-S4), partially improved Schwiderski ocean tides as resulting from PGM055, CIRA 86 drag model, IAU 1980 nutation series plus correction terms (Zhu/Reigber, 1991), earth tides (Zhu/Reigber, 1991). For the surface force modeling a satellite macro model consisting of eight pieces is used.

Besides the usual solve-for parameters (orbital elements, drag (4 per d), solar radiation, 1/rev empirical accelerations (cross-/along-track)) some PRARE specific parameters have been solved for: global time bias, range bias per station and one tropospheric scaling factor per pass. Especially the latter has been necessary as a number of stations is not yet equipped with a meteo station and so the data does not contain the meteorological information.

The following analysis is based on the onsite laser range normal points as delivered by the stations, the radar altimeter crossovers computed from ERS-2 OPR01 data and the PRARE range and doppler normal points as provided from the PRARE Masterstation at Oberpfaffenhofen. The PRARE data are preliminary revision 5 data which have better meteo information and an improved ionospheric correction.

POD Results

Based on the same models a number of orbits have been computed for the period weeks 7-11/96 with orbital fits of about 7 cm for range (same as SLR) and 0.5 - 0.7 mm/s for range rate. The following table presents the results (mean rms) of the orbit comparisons for the radial component. For the cross-track direction the numbers are only 2-3 cm higher, while for the along-track direction the numbers are going up to 18 cm due to differently estimated drag coefficients. In general it can be said that the orbits computed with different data sets (partially or totally independent) agree very well, less than 3 cm rms difference in radial direction. A plot of radial orbit differences is shown in Figure 3.

Table: ERS-2 POD Results: Mean RMS of Radial Orbit Differences (in cm, weeks 7-11/96)

Data used	SLR	PRA	PDO	SLR PRA	SLR PDO	PRA PDO	SLR Xover
PRA (Range)	2.6						
PDO (Doppler)	2.8	1.2					
SLR/PRA	2.3	0.6	1.2				
SLR/PDO	2.2	1.1	0.9	0.8			
PRA/PDO	2.6	0.4	1.1	0.7	1.0		
SLR/Xover	1.2	2.4	2.6	2.1	2.0	2.3	
SLR/PRA/PDO	2.3	0.7	1.1	0.4	0.7	0.4	2.1

Additionally crossover differences have been computed based on these orbits. For week 09/96 this shows a small improvement for the PRARE orbits compared to the laser ones: SLR and crossover (3.2 ± 11.0 cm) vs. SLR and PRARE (2.9 ± 10.9 cm) (from 997 crossovers).

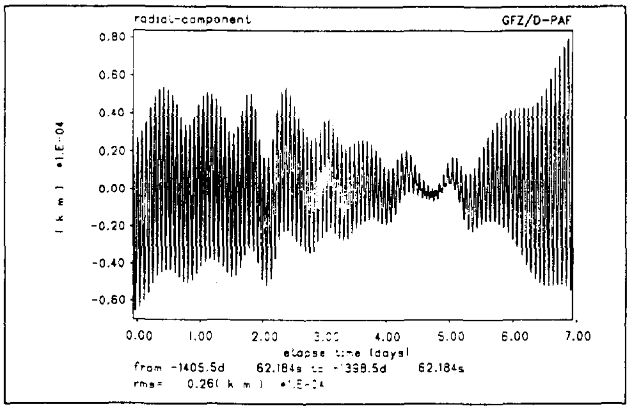

Fig.3: Radial difference of ERS-2 orbits: PRARE vs. SLR+Crossover

SUMMARY

The ERS-2 POD is already of high quality (7-9 cm radial accuracy). Since start of the PRARE routine phase the PRARE data has been used in the operational ERS-2 POD, resulting in orbits now free from influences of the sea surface. A comparison of orbits computed with different, partially independent tracking data shows the high consistency of the orbits, as they agree within a few cm. The improvement in the radial component is a few mm. Due to the continuous high data amount and the good distribution of the PRARE data in time and space, atmospheric effects can be estimated with a high resolution.

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